Impact of different domains of physical activity on cause-specific mortality: A longitudinal study

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Abstract: OBJECTIVE: To examine the associations between different domains of physical activity and all-cause, cardiovascular disease (CVD) and cancer mortality. METHODS: Participants (n=17,663, aged 16-92years) of two general population health studies conducted between 1977 and 1993 in Switzerland were included. Physical activity was assessed at baseline in the domains of commuting to work, work-related physical activity, and leisure-time physical activity (including leisure-time activity level and sport activity). A median follow-up time of 20.2years was obtained with anonymous record linkage providing 3878 deaths (CVD: 1357; cancer: 1351). Adjusted Cox proportional hazard models were calculated. RESULTS: There were no significant associations between commuting and work-related physical activities, respectively, and mortality. Leisure-time activity level was associated with all-cause mortality in men [adjusted hazard ratio (HR) 0.75, 95% confidence intervals (CI) 0.63-0.89] and women [HR 0.82 (0.74-0.91)], with CVD mortality in women only [HR 0.79 (0.67-0.94)] and with cancer mortality in men only [HR 0.63 (0.47-0.86)]. Sport activity was associated with all-cause, CVD and cancer mortality in men [HR ranged between 0.76 (0.63-0.92) and 0.85 (0.76-0.95)], but not in women. CONCLUSIONS: These results underline the public health relevance of physical activity for the prevention of CVD and cancer, especially regarding leisure-time physical activity.

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Impact of different domains of physical activity on cause-specific mortality: A longitudinal study

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Abstract

Objective

To examine the associations between different domains of physical activity and all-cause, cardiovascular disease (CVD) and cancer mortality.

Methods

Participants (n=17,663, aged 16-92 years) of two general population health studies conducted between 1977 and 1993 in Switzerland were included. Physical activity was assessed at baseline in the domains of commuting to work, work-related physical activity, and leisure-time physical activity (including leisure-time activity level and sport activity). A median follow-up time of 20.2 years was obtained with anonymous record linkage providing 3878 deaths (CVD: 1357; cancer: 1351). Adjusted Cox proportional hazard models were calculated.

Results

There were no significant associations between commuting and work-related physical activities, respectively, and mortality. Leisure-time activity level was associated with all-cause mortality in men [adjusted hazard ratio (HR) 0.75, 95% confidence intervals (CI) 0.63-0.89] and women [HR 0.82 (0.74-0.91)], with CVD mortality in women only [HR 0.79 (0.67-0.94)] and with cancer mortality in men only [HR 0.63 (0.47-0.86)]. Sport activity was associated with all-cause, CVD and cancer mortality in men [HR ranged between 0.76 (0.63-0.92) and 0.85 (0.76-0.95)], but not in women.

Conclusions

These results underline the public health relevance of physical activity for the prevention of CVD and cancer, especially regarding leisure-time physical activity.

Keywords

physical activity, mortality, cancer, cardiovascular disease, adults, Switzerland

Introduction

Being physically active decreases the risk of several diseases, including cardiovascular disease (CVD), some types of cancer, diabetes, and osteoporosis (Physical Activity Guidelines Advisory Committee, 2008). In a recent review and meta-analysis, physical activity was inversely associated with all-cause and cause-specific mortality (Nocon et al., 2008), however the strength of evidence differed by cause of death and by sex. While there was a decrease in cancer mortality with higher physical activity levels in men (Kampert et al., 1996; Laukkanen et al., 2011; Orsini et al., 2008), evidence was less clear in women (Kampert et al., 1996). In contrast, evidence for all-cause and CVD mortality is more consistent (Lollgen et al., 2009; Nocon et al., 2008; Woodcock et al., 2011). A meta-analysis showed a risk reduction of 35% for CVD mortality and of 33% for all-cause mortality in the most active compared to the least active participants (Nocon et al., 2008). However, the range of benefits varied considerably between the studies which often assessed different aspects of physical activity such as total physical activity or leisure-time physical activity (from 2% to 81% reduction in CVD and all-cause mortality risk). In order to support domain-specific physical activity promotion, it is important to identify the impact of the different domains of physical activity on health (Slingerland and Borghouts, 2011).

Associations between fitness and all-cause mortality (Blair et al., 1996; Syvaoja et al., 2013) and between physical activity and all-cause mortality (Lee and Paffenbarger, 2000; Paffenbarger et al., 1994) have been described. However, only few studies have investigated the association between different domains of physical activity and all-cause as well as cause-specific mortality, and the evidence is inconsistent (Andersen et al., 2000; Arrieta and Russell, 2008; Autenrieth et al., 2011; Barengo et al., 2004; Besson et al., 2008). Only few of the large cohort studies with data on physical activity and mortality have included women and relatively few deaths were observed, leaving uncertainty about the benefit of physical activity in women (Andersen et al., 2000). Therefore, it is appropriate to present the results of studies that also included women stratified by sex, as seen in other publications (Andersen et al., 2000; Barengo et al., 2004; Herzig et al., 2012).

In Switzerland, approximately 16,000 and 20,000 individuals died from cancer and CVD in 2010, respectively, accounting for more than 60% of all deaths (Federal

Statistical Office (FSO), 2010). Identifying modifiable risk factors associated with these health risks will help to develop promotional activities and allocate resources. The aim was to analyse the association between different domains of physical activity and all-cause, CVD and cancer mortality in a general population sample from Switzerland with a follow-up time of up to 32 years. Physical-activity domains under consideration were work-related physical activity, active commuting to work, and leisure-time physical activity (including leisure-time activity level and sport activity).

Methods

Study population

The sample (n=17,663, aged 16-92 years at baseline) included participants of two studies aimed at assessing and preventing CVD: the National Research Program 1A (NRP 1A) (Gutzwiller et al., 1985), and the Swiss MONICA (MONItoring of trends and determinants in CArdiovascular disease) study (Mattocks et al., 2008). The NRP 1A was conducted from 1977-79 in the three main language regions of Switzerland based on a random sample of 4378 and a convenience sample of 3873 participants (Bopp et al., 2012). The Swiss MONICA study was conducted in the French and Italian speaking parts of Switzerland in three waves between 1984 and 1993(Wietlisbach, 1987; Wietlisbach et al., 1997). Participants attended a health examination and completed a self-administered questionnaire. The questionnaire was only administered at baseline.

Mortality follow-up data were obtained up to 2008 by anonymous record linkage with data from the Swiss National Cohort (SNC) (Bopp et al., 2010; Bopp et al., 2012; Bopp et al., 2009). Approval (Nr. 13/06) was obtained from the Ethics Committee of the Canton of Zurich. Briefly, 8008 out of 8539 eligible (93.8%) participants of NRP 1A (Bopp et al., 2012) and 9853 out of 10,160 eligible MONICA participants (97.0%) could be linked with the SNC (Bopp et al., 2010). For the present analyses, 7890 NRP 1A participants (98.5%) were included accumulating 204,095 person-years of follow-up and 2370 deaths. 500 individuals were excluded due to missing data. From the MONICA study, 9773 participants (99.2%) were included accumulating 174,700 person-years and 1508 deaths. 165 individuals were excluded due to missing data. The final dataset included 17,663 individuals, 378,795 person-years of follow-up and 3878 deaths (1357 due to CVD and 1351 due to cancer).

Measurements

Self-reported current physical activity as exposure variable was available in the following domains: transportation (number of minutes per day of active commuting (cycling or walking) to work), work-related physical activity (intensity of professional activity), and leisure-time physical activity, including frequency of "sport activity" (more than once a week, once a week, and less or never) and "leisure-time activity level" (low, moderate, high). The questions and categorisations are available in the Appendix. The categorization of the work-related variable was driven by the slightly different assessment in the two surveys.

Apart from the physical activity variables, we used the following covariates: sex, age (in years), educational level (according to the International Standard Classification of Education ISCED: mandatory school, vocational education, higher vocational education, university), marital status (single, married, widowed, divorced/separated), survey (NRP 1A, MONICA), smoking (never smoker, former smoker, light smoker, heavy smoker), diet (having three regular meals per day: breakfast, lunch, dinner; based on evidence that skipping meals such as breakfast is associated with an increased risk of coronary heart disease (Cahill et al., 2013)), body mass index (BMI) based on measured height and weight (kg/m^2), systolic blood pressure (mm Hg), and cholesterol (mmol/l).

The outcome was defined as all-cause mortality and cause-specific mortality (CVD: ICD-8: 410-438; ICD-10: I00-I99; cancer: ICD-8: 140-239; ICD-10: C00-C99; D00-D48). In Switzerland, causes of death were coded based on ICD-8 until 1994 and based on ICD-10 from 1995 on.

Statistical analyses

Associations between physical activity and mortality were calculated using Cox proportional hazard models and displayed as hazard ratios (HR) and 95% confidence intervals (95% CI). Time to event was the difference between start time (date of baseline interview) and stop time (date of death, emigration or end of study on December 31, 2008). In a first step, all domains of physical activity were included in one model with the outcome all-cause mortality. In this model, only persons with occupation working ≥50% ("working population") were used for analysis since work-related physical activity and active commuting to work was only available for those participants. Because the associations between work-related or commuting activities,

respectively, and all-cause mortality were statistically not significant (see result section), cause-specific mortality was analysed only for leisure-time activity level and sport activity. This also increased the sample size and the number of deaths, especially for women, as all individuals and not only the working population could be included in the analyses. Therefore, in a second step, leisure-time activity level and sport activity were entered into the models separately because of high correlation between these two variables (data not shown).

Akaike's information criterion (AIC) and the Bayesian information criterion (BIC) were used for model choice. The following adjustments were made: Model 1 for the socio-demographic variables sex, age, educational level, marital status, and survey; Model 2 additionally for the behavioural variables smoking and diet; Model 3 additionally for the clinical/biological variables BMI, blood pressure and cholesterol. Models 3 are presented in the Electronic Supplementary Material only, since these physiological parameters may also be intermediate variables on the causal pathway between physical activity and mortality, and controlling for them may therefore result in over-adjustment (Bundesamt für Statistik BFS, 2013). In view of the lack of data on the association between physical activity and mortality in women (Andersen et al., 2000; Barengo et al., 2004), the analyses were computed also stratified by gender, even though formal testing for interaction between gender and the physical activity variables did not reveal significant results. Age-standardised mortality rates (based on Switzerland's population on December 31, 1990) were calculated per 100,000 person-years for different combinations of sport and leisure-time activity levels for men and women separately.

Statistical significance was set at $p<0.05$. Analyses were carried out using STATA version 12 (StataCorp LP, College Station, Texas, 2011).

Results

Characteristics of participants

The characteristics of the participants are shown in Table 1 separately for the entire population and for the working population. The proportion of women was 51.1%, the mean age 45.0 years. On average, men had higher educational levels than women, were more often former and heavy smokers, were more likely to be married and less likely to have three regular meals per day.

MONICA participants were older than NRP 1A participants (men 47.0 versus 42.0 years, women 47.3 versus 43.3 years); this is due to the inclusion of participants aged 25-74 years only in MONICA while in NRP 1A the lower age limit was 16 years. Probably due to the same reason, a higher proportion of MONICA participants was married (men 80.2% versus 73.9%, women 74.0% versus 65.8%) and had a higher educational level (men 10.5% versus 6.6%, women 4.5% versus 1.4% with a university degree).
The total person-years of follow-up are shown in Table 1, the median follow-up time was 20.0 years for men and 22.6 years for women.

All-cause mortality

As shown in Table 2 and in Electronic Supplementary Material Table 1 (working population only), there were no significant associations between active commuting to work or physical activity at work and all-cause mortality (adjusted HR per 10 minutes of commuting 1.01 (0.98-1.04); for high versus low work-related activity 1.01 (0.88-1.15)). These domains were therefore not included in further analyses with cause-specific mortality.
As shown in Table 3 and in Electronic Supplementary Material Table 2 (including the entire sample and not only the working population), higher leisure-time activity level was associated with lower all-cause mortality in men and women combined with indications of a dose-response relationship (adjusted HR for moderate versus low leisure-time activity levels 0.88 (0.82-0.94), for high versus low 0.73 (0.63-0.85)). There were only small effect reductions when including behavioural and clinical/biological variables as potential confounders. Protective effects were also observed for sport activity, however without apparent dose-response relationship (adjusted HR for sport once a week versus less 0.82 (0.75-0.90), for sport several times per week versus less than once a week 0.88 (0.81-0.96)). Again, effect reductions were small after including behavioural and clinical/biological variables.
When analysing men and women separately, effect sizes for leisure-time activity levels on all-cause mortality were similar in both sexes with indications for a dose-response relationship. The effects of sport activity were stronger in men and mostly not significant in women. There were no dose-response effects in either sex.
Figure 1 shows the age-standardised mortality rates for combinations of sport and leisure-time physical activity levels for men and women. In men, for any level of

sport activity, mortality rates tended to be lower in higher intensity levels of leisure-time activity. In women, the patterns were less pronounced. As indicated by the large confidence intervals, the number of individuals and the number of deaths in some strata were very small.

CVD mortality

Similar associations regarding size and dose-response effects as for all-cause mortality were found between leisure-time activity levels and CVD mortality in men and women combined (moderate versus low HR 0.88 (0.78-0.99), high versus low 0.81 (0.62-1.06)). For sport activity, effects were smaller than for all-cause mortality and not significant (once a week versus less HR 0.91 (0.78-1.06), several times per week versus less 0.92 (0.79-1.04)). The effects of leisure-time activity levels on CVD mortality were larger in women compared to men and suggested a dose-response pattern. Sport activity was significantly associated with CVD mortality only in men, with no apparent dose-response effect.

Cancer mortality

The effects of leisure-time activity level were also similar for cancer mortality in men and women combined, except that a moderate leisure-time activity level was not significantly associated with cancer mortality after inclusion of behavioural variables (moderate versus low HR 0.92 (0.82-1.04), high versus low 0.69 (0.54-0.90)).
Regarding sport activity and cancer mortality, effects were similar to those for all-cause mortality but with smaller magnitude (once a week versus less HR 0.86 (0.74-1.00), several times per week versus less 0.80 (0.60-1.03)).
For leisure-time activity levels, dose-response effects were observed in men but not in women. Again, effects of sport activity were stronger in men than in women with a tendency for a dose-response effect in both sexes.

Discussion

In this study, higher levels of leisure-time physical activity in the form of sport activity and leisure-time activity levels were associated with lower all-cause mortality while work-related physical activity and walking and cycling to work were not. Leisure-time activity levels were also associated with lower CVD and cancer mortality in a dose-response manner. Regarding CVD mortality, effects were stronger for women than for men, while for cancer mortality, the effects were stronger for men

than for women. Sport activity was more protective in men than in women for all-cause and cancer mortality and had no impact on CVD mortality in women.

The relationship between leisure-time physical activity and all-cause (Lee and Skerrett, 2001; Samitz et al., 2011) and cause-specific mortality (Autenrieth et al., 2011; Laukkanen et al., 2011) has been reported previously. According to a meta-analysis, risk reductions for all-cause mortality per additional unit of time were largest for vigorous exercise (not separately reported for men and women) (Samitz et al., 2011); highest risk reductions for all-cause and CVD mortality for sport and exercise were also found by others (Besson et al., 2008).

Sport activity and leisure-time activity levels showed different associations with mortality and were also sex-dependent. In line with another study, we did not find a significant effect of physical activity on cancer mortality in women (Table 3) (Kampert et al., 1996). However, a study reported significant effects in women but not in men (Patel et al., 2010). Because the strongest evidence for a protective effect – besides for colon cancer - is available for breast cancer (Physical Activity Guidelines Advisory Committee, 2008), stronger associations in women could be expected. On the other hand, there is also growing evidence suggesting an association between increased physical activity levels and lung cancer (Physical Activity Guidelines Advisory Committee, 2008) which may explain stronger associations in men.

As suggested in Figure 1, there was a tendency that higher leisure-time activity levels were associated with lower mortality rates for any level of sport activity. In men, this pattern was apparent for all sport categories, while in women this was less clear. However, the confidence intervals were large for some categories (especially in individuals with high leisure-time activity levels) and overlapping, rendering interpretation difficult. Interestingly, some effects were as strong as or even stronger for cancer mortality than for CVD mortality, as has been reported in other studies, e.g. for leisure-time physical activity (Autenrieth et al., 2011). While there is evidence for a protective effect of physical activity on the general circulatory system (Physical Activity Guidelines Advisory Committee, 2008), strong evidence for a protective effect against cancer is mainly available for colon and breast cancer, while moderate evidence suggests an association between physical activity and lung, endometrial and ovarian cancers (Physical Activity Guidelines Advisory Committee, 2008; World Cancer Research Fund and American Institute for Cancer Research, 2007).

In line with (Autenrieth et al., 2011; Besson et al., 2008) and in contrast to (Andersen et al., 2000; Samitz et al., 2011) others, we found no significant association between walking or cycling to work and all-cause mortality. This inconsistency may be explained by country-specific physical environments present for active commuting or by different measurement instruments. For example, Andersen et al. (Andersen et al., 2000) focused on cycling to work while in our study both walking and cycling were included. Analyses of the association between work-related physical activity and mortality provided conflicting results. They range from a protective effect (Autenrieth et al., 2011; Barengo et al., 2004; Samitz et al., 2011) to no effects (Besson et al., 2008) (in line with our results) to deleterious effects, at least in men (Herzig et al., 2012). Null findings between occupational physical activity and mortality may be due to residual confounding or the broad physical activity categorisation due to job type only.

Additionally adjusting the models for clinical/biological parameters did not substantially change the results (see Electronic Supplementary Material Table 1 and 2). Thus, we did not present the results in the main manuscript. Another reason is that, depending on the causes of death, parameters such as BMI, blood pressure or cholesterol may also be intermediate variables on the causal pathway between physical activity and mortality.

The strengths of this study are the large sample size, the long follow-up period, the domain-specific information on physical activity behaviour at baseline, and the small loss-to-follow-up. Some limitations need to be addressed. Physical activity was only assessed once at baseline and potential changes during the follow-up period could not be considered. This may in part explain the lack of association between work-related or commuting activity and mortality. Furthermore, physical activity behaviour was based on broad self-report measures vulnerable for measurement error; e.g. duration was available for active commuting while only intensity was available for leisure-time and work-related activity, and only frequency was available for sport activity. However, crude measures usually dilute effects and the real effects are therefore likely to be more pronounced than the reported estimates. This is also supported by the fact that studies using more accurate measures reported lower HR (Autenrieth et al., 2011; Zhao et al., 2013). A further limitation was that we had information only on mortality, not on morbidity. Due to small numbers, it was not possible to look at cancer-specific mortality. In line with other health surveys, the NRP 1A participants

were most likely healthier than the general population (Bopp et al., 2010). Finally, we could not include some potential confounders such as more accurate dietary data, alcohol intake and medication use.

Conclusions

In conclusion, this study underlines the public health relevance of physical activity contributing to the prevention of CVD and cancer, especially regarding leisure-time physical activity. In contrast to others (Andersen et al., 2000; Autenrieth et al., 2011; Barengo et al., 2004; Samitz et al., 2011), there were no effects of work-related and commuting activities on mortality. The promotion of physical activity offers large potential for health improvement and mortality reduction in the population. Future studies using more accurate measurement instruments may better disentangle the effects of commuting and work-related activity also for Switzerland.

Conflict of interest

The authors declare that there are no conflicts of interest.

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References

Andersen LB, Schnohr P, Schroll M, Hein HO, 2000. All-cause mortality associated with physical activity during leisure time, work, sports, and cycling to work. Arch Intern Med 160:1621-8.

Arrieta A, Russell LB, 2008. Effects of leisure and non-leisure physical activity on mortality in U.S. adults over two decades. Ann Epidemiol 18:889-95. doi:10.1016/j.annepidem.2008.09.007.

Autenrieth CS, Baumert J, Baumeister SE, Fischer B, Peters A, Doring A, Thorand B, 2011. Association between domains of physical activity and all-cause, cardiovascular and cancer mortality. Eur J Epidemiol 26:91-9. doi:10.1007/s10654-010-9517-6.

Barengo NC, Hu G, Lakka TA, Pekkarinen H, Nissinen A, Tuomilehto J, 2004. Low physical activity as a predictor for total and cardiovascular disease mortality in middle-aged men and women in Finland. Eur Heart J 25:2204-11. doi:10.1016/j.ehj.2004.10.009.

Besson H, Ekelund U, Brage S, Luben R, Bingham S, Khaw KT, Wareham NJ, 2008. Relationship between subdomains of total physical activity and mortality. Med Sci Sports Exerc 40:1909-15. doi:10.1249/MSS.0b013e318180bcad.

Blair SN, Kampert JB, Kohl HW, 3rd, Barlow CE, Macera CA, Paffenbarger RS, Jr., Gibbons LW, 1996. Influences of cardiorespiratory fitness and other precursors on cardiovascular disease and all-cause mortality in men and women. JAMA 276:205-10.

Bopp M, Braun J, Faeh D, Gutzwiller F, 2010. Establishing a follow-up of the Swiss MONICA participants (1984-1993): record linkage with census and mortality data. BMC Public Health 10:562. doi:10.1186/1471-2458-10-562.

Bopp M, Braun J, Gutzwiller F, Faeh D, 2012. Health Risk or Resource? Gradual and Independent Association between Self-Rated Health and Mortality Persists Over 30 Years. PLoS One 7:e30795. doi:10.1371/journal.pone.0030795.

Bopp M, Spoerri A, Zwahlen M, Gutzwiller F, Paccaud F, Braun-Fahrlander C, Rougemont A, Egger M, 2009. Cohort Profile: the Swiss National Cohort--a longitudinal study of 6.8 million people. Int J Epidemiol 38:379-84. doi:10.1093/ije/dyn042.

Bundesamt für Statistik BFS, 2013. Schweizerische Gesundheitsbefragung 2012 - Übersicht. Bundesamt für Statistik, Neuchâtel.

Cahill LE, Chiuve SE, Mekary RA, Jensen MK, Flint AJ, Hu FB, Rimm EB, 2013. Prospective Study of Breakfast Eating and Incident Coronary Heart Disease in a Cohort of Male US Health Professionals. Circulation 128:337-43. doi:10.1161/CIRCULATIONAHA.113.001474.

Federal Statistical Office (FSO), 2010. Mortality, causes of death - Data, Indicators.

Gutzwiller F, Nater B, Martin J, 1985. Community-based primary prevention of cardiovascular disease in Switzerland: methods and results of the National Research Program (NRP 1A). Prev Med 14:482-91.

Herzig M, Dossegger A, Mader U, Kriemler S, Wunderlin T, Grize L, Brug J, Manios Y, Braun-Fahrlander C, et al., 2012. Differences in weight status and energy-balance related behaviors among schoolchildren in German-speaking Switzerland compared to seven countries in Europe. Int J Behav Nutr Phys Act 9:139. doi:10.1186/1479-5868-9-139.

Kampert JB, Blair SN, Barlow CE, Kohl HW, 3rd, 1996. Physical activity, physical fitness, and all-cause and cancer mortality: a prospective study of men and women. Ann Epidemiol 6:452-7. doi:S1047279796000592 [pii].

Laukkanen JA, Rauramaa R, Makikallio TH, Toriola AT, Kurl S, 2011. Intensity of leisure-time physical activity and cancer mortality in men. Br J Sports Med 45:125-9. doi:10.1136/bjsm.2008.056713.

Lee IM, Paffenbarger RS, Jr., 2000. Associations of light, moderate, and vigorous intensity physical activity with longevity. The Harvard Alumni Health Study. Am J Epidemiol 151:293-9.

Lee IM, Skerrett PJ, 2001. Physical activity and all-cause mortality: what is the dose-response relation? Med Sci Sports Exerc 33:S459-71; discussion S93-4.

Lollgen H, Bockenhoff A, Knapp G, 2009. Physical activity and all-cause mortality: an updated meta-analysis with different intensity categories. Int J Sports Med 30:213-24. doi:10.1055/s-0028-1128150.

Mattocks C, Ness A, Leary S, Tilling K, Blair SN, Shield J, Deere K, Saunders J, Kirkby J, et al., 2008. Use of accelerometers in a large field-based study of children: protocols, design issues, and effects on precision. J Phys Act Health 5 Suppl 1:S98-111.

Nocon M, Hiemann T, Muller-Riemenschneider F, Thalau F, Roll S, Willich SN, 2008. Association of physical activity with all-cause and cardiovascular mortality: a systematic review and meta-analysis. Eur J Cardiovasc Prev Rehabil 15:239-46. doi:10.1097/HJR.0b013e3282f55e09.

Orsini N, Mantzoros CS, Wolk A, 2008. Association of physical activity with cancer incidence, mortality, and survival: a population-based study of men. Br J Cancer 98:1864-9. doi:10.1038/sj.bjc.6604354.

Paffenbarger RS, Jr., Kampert JB, Lee IM, Hyde RT, Leung RW, Wing AL, 1994. Changes in physical activity and other lifeway patterns influencing longevity. Med Sci Sports Exerc 26:857-65.

Patel AV, Bernstein L, Deka A, Feigelson HS, Campbell PT, Gapstur SM, Colditz GA, Thun MJ, 2010. Leisure time spent sitting in relation to total mortality in a prospective cohort of US adults. Am J Epidemiol 172:419-29. doi:kwq155 [pii]

10.1093/aje/kwq155.

Physical Activity Guidelines Advisory Committee, 2008. Physical Activity Guidelines Advisory Committee Report 2008. U.S. Department of Health and Human Services, Washington, DC.

Samitz G, Egger M, Zwahlen M, 2011. Domains of physical activity and all-cause mortality: systematic review and dose-response meta-analysis of cohort studies. Int J Epidemiol 40:1382-400. doi:10.1093/ije/dyr112.

Slingerland M, Borghouts L, 2011. Direct and indirect influence of physical education-based interventions on physical activity: a review. J Phys Act Health 8:866-78.

Syvaoja HJ, Kantomaa MT, Ahonen T, Hakonen H, Kankaanpaa A, Tammelin TH, 2013. Physical Activity, Sedentary Behavior, and Academic Performance in Finnish Children. Med Sci Sports Exerc. doi:10.1249/MSS.0b013e318296d7b8.

Wietlisbach V, 1987. Théorie et pratique de l'échantillonnage: l'exemple de l'enquête MONICA. Soz Praeventivmed 32:52-62. doi:10.1007/bf02083851.

Wietlisbach V, Paccaud F, Rickenbach M, Gutzwiller F, 1997. Trends in cardiovascular risk factors (1984-1993) in a Swiss region: results of three population surveys. Prev Med 26:523-33. doi:10.1006/pmed.1997.0167.

Woodcock J, Franco OH, Orsini N, Roberts I, 2011. Non-vigorous physical activity and all-cause mortality: systematic review and meta-analysis of cohort studies. Int J Epidemiol 40:121-38. doi:10.1093/ije/dyq104.

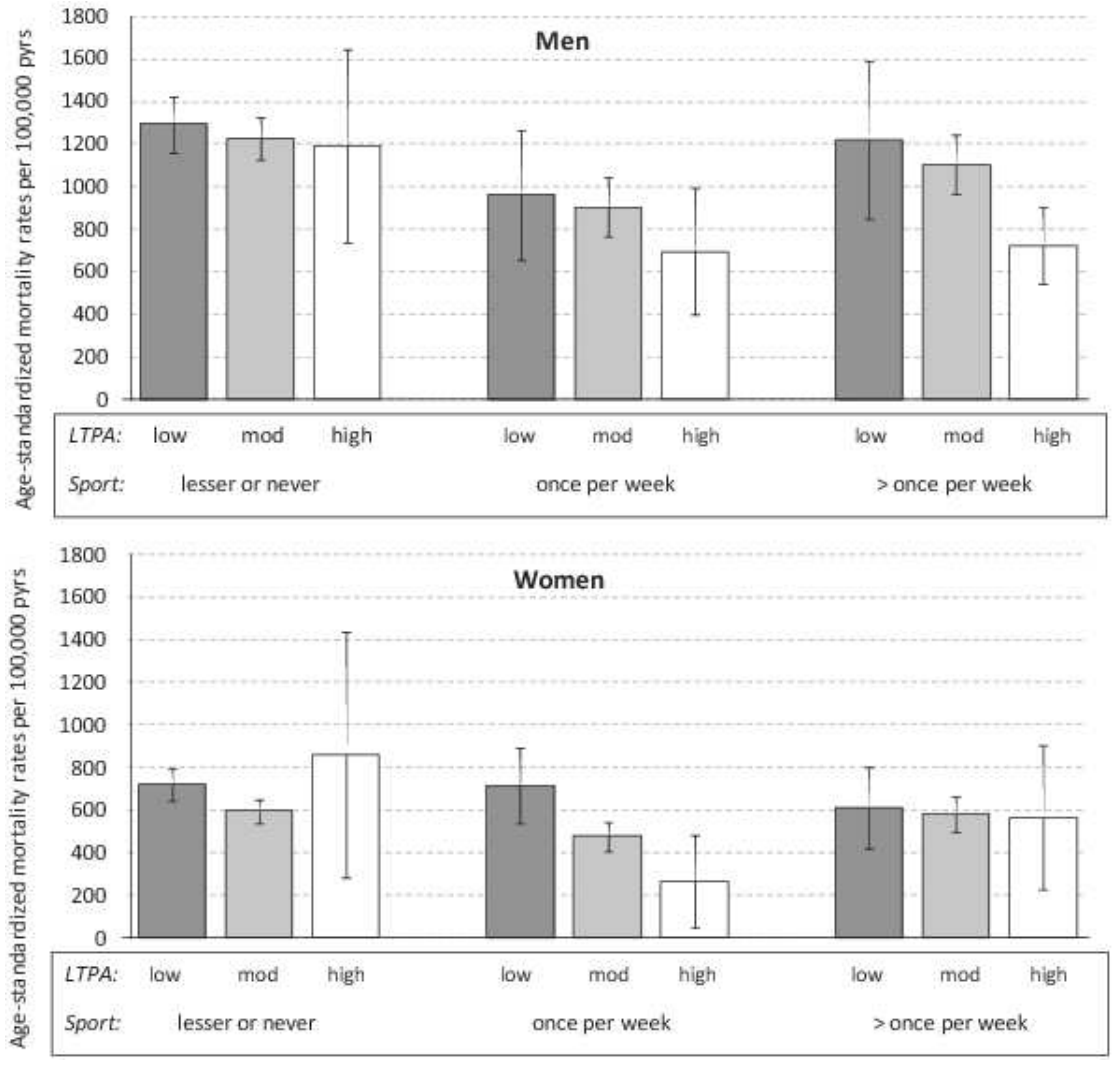
World Cancer Research Fund, American Institute for Cancer Research, 2007. Food, Nutrition, Physical Activity, and the Prevention of Cancer: a Global Perspective. AICR, Washington DC.

Zhao G, Li C, Ford ES, Fulton JE, Carlson SA, Okoro CA, Wen XJ, Balluz LS, 2013. Leisure-time aerobic physical activity, muscle-strengthening activity and mortality risks among US adults: the NHANES linked mortality study. Br J Sports Med. doi:10.1136/bjsports-2013-092731

bjsports-2013-092731 [pii].

Figure 1 - Standardised mortality rates according to levels of leisure-time activity level and sport activity, by sex (MONICA and NRP 1A, Switzerland, 1977-2008)

LTPA: leisure-time activity level



Tables

Table 1 - Baseline characteristics of participants (MONICA and NRP 1A, Switzerland, 1977-1993)

		"Working population"[a)]		Total population	
		Men	Women	Men	Women
N		6942	3439	8585	9078
Mean age(years)		43.3	40.9	44.9	45.4
Person-years		148,393	78,108	177,749	201,046
Number of deaths	all causes	1365	379	2148	1730
	CVD	425	91	742	615
	cancer	526	176	759	592
Professional status	employed ≥50%	100	100	85.2	40.3
	housewife/-man	0	0	0.2	49.2
	employed <50% or unemployed	0	0	14.6	10.5
Educational level	mandatory(%)	25.3	33.6	28.0	41.5
	vocational(%)	51.7	47.8	50.1	44.8
	higher vocational (%)	13.6	13.8	13.1	10.7
	university (%)	9.4	4.9	8.8	3.0
Marital status	single (%)	14.5	28.2	16.4	16.2
	married (%)	79.8	55.7	77.5	70.2
	widowed (%)	0.8	4.2	1.3	7.3
	divorced/separated (%)	4.9	11.9	4.8	6.3
Smoking status	never (%)	35.1	55.6	35.8	63.8
	former (%)	23.7	10.6	23.7	9.9
	light (1-19 cig./day, %)	17.0	20.5	17.3	17.0
	heavy (≥20 cig./day, %)	24.2	13.4	23.2	9.3
3 regular meals per day (breakfast, lunch, dinner)	yes (%)	62.9	64.3	64.9	74.1
Mean BMI (kg/m2)		25.6	23.5	25.6	24.1
Active commuting	>0 min/day (%)	36.4	43.7	32.9	18.9
	all (including individuals reporting none (min/day))	7.6	9.7	7.7	4.5
	only individuals reporting some (min/day)	20.9	22.2	20.9	22.2
Work-related physical activity	high (%)	18.7	6.6	18.2	4.6
Leisure-time physical activity	low (%)	28.0	36.5	27.6	33.3
	moderate (%)	56.1	56.4	57.1	61.1
	high (%)	15.9	7.1	15.3	5.6

Sport activity	less than once a week or never (%)	54.4	57.6	54.6	57.1
	once a week (%)	22.3	23.4	20.8	23.4
	several times per week or daily (%)	23.4	19.0	24.6	19.5

[a)] only those participants that were employed ≥50%

Table 2 - Hazard Ratios (HR) for different domains of physical activity and all-cause mortality (MONICA and NRP 1A, Switzerland, 1977-2008)

			Men and women[c]		Men		Women	
			Model 1[a]	Model 2[b]	Model 1[a]	Model 2[b]	Model 1[a]	Model 2[b]
			HR (95%-CI)	HR (95%-CI)	HR (95%-CI)	HR (95%-CI)	HR (95%-CI)	HR (95%-CI)
	Active commuting	per 10 minutes	0.99 (0.96-1.02)	1.01 (0.98-1.04)	0.99 (0.96-1.03)	1.01 (0.98-1.05)	0.98 (0.92-1.04)	0.99 (0.93-1.05)
	Work-related physical activity	low/moderate	1.00	1.00	1.00	1.00	1.00	1.00
		high	1.04 (0.91-1.18)	1.01 (0.88-1.15)	1.05 (0.92-1.21)	1.02 (0.89-1.18)	0.84 (0.55-1.27)	0.83 (0.54-1.26)
Leisure-time physical activity	Leisure-time activity level	low	1.00	1.00	1.00	1.00	1.00	1.00
		moderate	0.92 (0.83-1.02)	0.97 (0.87-1.09)	0.92 (0.81-1.04)	0.97 (0.85-1.09)	0.92 (0.73-1.16)	0.98 (0.78-1.24)
		high	0.74 (0.60-0.91)	0.80 (0.65-0.98)	0.74 (0.59-0.92)	0.80 (0.64-1.00)	0.76 (0.41-1.41)	0.80 (0.43-1.49)
	Sport activity	less than once a week or never	1.00	1.00	1.00	1.00	1.00	1.00
		once a week	0.79 (0.69-0.90)	0.83 (0.73-0.95)	0.78 (0.67-0.91)	0.83 (0.71-0.97)	0.82 (0.63-1.08)	0.86 (0.65-1.13)
		several times per week or daily	0.88 (0.77-1.00)	0.91 (0.80-1.04)	0.87 (0.75-1.01)	0.91 (0.78-1.06)	0.92 (0.68-1.25)	0.94 (0.70-1.28)

[a] Adjusted for socio-demographic variables (age, educational level, marital status), survey and all domains of physical activity

[b] Additionally adjusted for behavioural variables (smoking, nutrition)

[c] Also adjusted for gender

Note: analyses restricted to working population (N=10,381)

Table 3 - Hazard Ratios (HR) for leisure-time and sport activity and all-cause, CVD and cancer mortality (MONICA and NRP 1A, Switzerland, 1977-2008)

			Men and women[c]		Men		Women	
			Model 1[a]	Model 2[b]	Model 1[a]	Model 2[b]	Model 1[a]	Model 2[b]
			HR (95%-CI)	HR (95%-CI)	HR (95%-CI)	HR (95%-CI)	HR (95%-CI)	HR (95%-CI)
All-cause mortality	Leisure-time activity level	low	1.00	1.00	1.00	1.00	1.00	1.00
		moderate	0.84 (0.78-0.90)	0.88 (0.82-0.94)	0.87 (0.79-0.96)	0.92 (0.84-1.02)	0.79 (0.72-0.88)	0.82 (0.74-0.91)
		high	0.68 (0.58-0.79)	0.73 (0.63-0.85)	0.68 (0.57-0.91)	0.75 (0.63-0.89)	0.76 (0.53-1.08)	0.74 (0.52-1.05)
	Sport activity	less than once a week or never	1.00	1.00	1.00	1.00	1.00	1.00
		once a week	0.79 (0.72-0.86)	0.82 (0.75-0.90)	0.73 (0.64-0.83)	0.77 (0.67-0.87)	0.85 (0.75-0.97)	0.89 (0.78-1.01)
		several times per week or daily	0.85 (0.78-0.92)	0.88 (0.81-0.96)	0.80 (0.72-0.89)	0.85 (0.76-0.95)	0.91 (0.80-1.03)	0.94 (0.82-1.07)
CVD mortality	Leisure-time activity level	low	1.00	1.00	1.00	1.00	1.00	1.00
		moderate	0.84 (0.75-0.95)	0.88 (0.78-0.99)	0.94 (0.79-1.10)	0.98 (0.83-1.16)	0.77 (0.65-0.91)	0.79 (0.67-0.94)
		high	0.76 (0.58-0.99)	0.81 (0.62-1.06)	0.84 (0.62-1.12)	0.92 (0.68-1.23)	0.46 (0.19-1.12)	0.44 (0.18-1.06)
	Sport activity	less than once a week or never	1.00	1.00	1.00	1.00	1.00	1.00
		once a week	0.88 (0.75-1.02)	0.91 (0.78-1.06)	0.77 (0.62-0.96)	0.79 (0.63-0.98)	1.02 (0.85-1.27)	1.06 (0.85-1.32)

		several times per week or daily	0.87 (0.76-1.00)	0.92 (0.79-1.04)	0.79 (0.66-0.95)	0.82 (0.69-0.99)	1.02 (0.83-1.26)	1.05 (0.85-1.30)
Cancer mortality	Leisure-time activity level	low	1.00	1.00	1.00	1.00	1.00	1.00
		moderate	0.86 (0.77-0.97)	0.92 (0.82-1.04)	0.84 (0.72-0.98)	0.91 (0.77-1.06)	0.87 (0.73-1.04)	0.91 (0.76-1.09)
		high	0.64 (0.49-0.82)	0.69 (0.54-0.90)	0.56 (0.41-0.75)	0.63 (0.47-0.86)	1.04 (0.65-1.66)	1.04 (0.66-1.66)
	Sport activity	less than once a week or never	1.00	1.00	1.00	1.00	1.00	1.00
		once a week	0.82 (0.70-0.95)	0.86 (0.74-1.00)	0.77 (0.63-0.95)	0.83 (0.67-1.02)	0.88 (0.71-1.09)	0.91 (0.73-1.13)
		several times per week or daily	0.76 (0.66-0.88)	0.80 (0.60-1.03)	0.70 (0.58-0.85)	0.76 (0.63-0.92)	0.84 (0.67-1.05)	0.87 (0.69-1.09)

[a)] Adjusted for socio-demographic variables (age, educational level, marital status) and survey

[b)] Additionally adjusted for behavioural variables (smoking, nutrition)

[c)] Also adjusted for gender

Note: analyses include the whole population with available data for leisure-time activity level (men: N=8515, women: N=8949) or sport activity (men: N=8481, women: N=8914); leisure-time activity level and sport activity were entered separately into the models

Appendix

Physical activity questions and operationalisation for analyses

Question:	Operationalisation for analyses:	
Active commuting		
Mean daily duration (in minutes) of active transport (walking and cycling) between home and workplace?	mean minutes per day (min/day)	
Work-related physical activity		
Which of the following four statements best describes your physical activity level during your work or in the household?		
1) I am mostly sitting during work and do only move rarely.		
2) During my work, I am mostly standing and walk frequently, but I don't have to lift or carry heavy objects.	1, 2 and 3 4	= low = high
3) During my work, I often have to take the stairs or I have to carry relatively light objects.		
4) My work is usually associated with an important physical effort, I frequently have to lift or carry heavy objects.		
Leisure time activity level		
Which statement best describes your activity level during leisure-time, including sports?		
1) Light physical activity, mostly sedentary	1	= low
2) Frequent walking or cycling; other frequent activities such as gardening	2 3	= moderate = high
3) Regular vigorous physical activity		
Sport activity		
How often, on average, do you participate in sport?		
1) Every day	1, 2	= several times per week or daily
2) Several times a week	3	= once a week
3) Once a week	4, 5	= less than once a week or never
4) Less than once a week		
5) never		

Electronic Supplementary Material

ESM Table 1 – Hazard Ratios (HR) for different domains of physical activity and all-cause mortality, full models

			Men and women[b]	Men	Women
			Model 3[a]	Model 3[a]	Model 3[a]
			HR (95%-CI)	HR (95%-CI)	HR (95%-CI)
	Active commuting	per 10 minutes	1.01 (0.98-1.04)	1.02 (0.99-1.06)	0.98 (0.92-1.04)
	Work-related physical activity	low/moderate	1.00	1.00	1.00
		high	0.99 (0.87-1.14)	1.01 (0.88-1.17)	0.81 (0.53-1.23)
Leisure-time physical activity	Leisure-time activity level	low	1.00	1.00	1.00
		moderate	0.98 (0.88-1.09)	0.97 (0.86-1.10)	0.97 (0.77-1.24)
		high	0.82 (0.67-1.01)	0.82 (0.66-1.02)	0.86 (0.46-1.59)
	Sport activity	less than once a week or never	1.00	1.00	1.00
		once a week	0.85 (0.74-0.97)	0.84 (0.72-0.98)	0.87 (0.66-1.15)
		several times per week or daily	0.92 (0.80-1.05)	0.92 (0.79-1.07)	0.94 (0.69-1.28)

[a] Adjusted for socio-demographic variables (age, educational level, marital status), survey, all domains of physical activity, behavioural variables (smoking, nutrition) and physiological parameters (BMI, blood pressure, cholesterol)

[b] Also adjusted for gender

Note: analyses restricted to working population (N=10'381)

ESM Table 2 – Hazard Ratios (HR) for leisure-time and sport activity and all-cause, CVD and cancer mortality, full models

			Men and women[b)]	Men	Women
			Model 3[a)]	Model 3[a)]	Model 3[a)]
			HR (95%-CI)	HR (95%-CI)	HR (95%-CI)
All-cause mortality	Leisure-time activity level	low	1.00	1.00	1.00
		moderate	0.90 (0.84-0.97)	0.93 (0.84-1.03)	0.86 (0.77-0.95)
		high	0.75 (0.65-0.88)	0.76 (0.64-0.91)	0.78 (0.55-1.12)
	Sport activity	less than once a week or never	1.00	1.00	1.00
		once a week	0.84 (0.76-0.92)	0.77 (0.68-0.88)	0.91 (0.80-1.04)
		several times per week or daily	0.90 (0.83-0.98)	0.86 (0.77-0.96)	0.96 (0.84-1.09)
CVD mortality	Leisure-time activity level	low	1.00	1.00	1.00
		moderate	0.90 (0.80-1.02)	0.99 (0.84-1.17)	0.82 (0.68-0.97)
		high	0.82 (0.62-1.08)	0.91 (0.68-1.23)	0.48 (0.20-1.17)
	Sport activity	less than once a week or never	1.00	1.00	1.00
		once a week	0.93 (0.79-1.09)	0.80 (0.64-1.00)	1.11 (0.89-1.38)
		several times per week or daily	0.90 (0.78-1.04)	0.82 (0.68-0.98)	1.05 (0.84-1.30)
Cancer mortality	Leisure-time activity level	low	1.00	1.00	1.00
		moderate	0.95 (0.84-1.07)	0.92 (0.78-1.08)	0.96 (0.80-1.15)
		high	0.74 (0.58-0.96)	0.66 (0.49-0.90)	1.15 (0.72-1.84)
	Sport activity	less than once a week or never	1.00	1.00	1.00
		once a week	0.87 (0.75-1.02)	0.82 (0.67-1.01)	0.92 (0.74-1.15)
		several times per week or daily	0.82 (0.71-0.95)	0.77 (0.64-0.94)	0.90 (0.72-1.14)

[a)] Adjusted for socio-demographic variables (age, educational level, marital status), survey wave, all domains of physical activity, behavioural variables (smoking, nutrition) and physiological parameters (BMI, blood pressure, cholesterol)

[b)] Also adjusted for gender

Note: analyses include the whole population with available data for leisure-time activity level (men: N=8515, women: N=8949) or sport activity (men: N=8481, women: N=8914); leisure-time activity level and sport activity were entered separately into the models